Appendix D

Water Quality Environmental Effects Determination Methodology Supplemental Information

D.1 Available Numeric Models for Analysis of the Proposed Project and Alternatives

D.1.1 Klamath River Water Quality Model (KRWQM)

Numeric models[6] used to assess potential water quality impacts for the Proposed Project and Alternatives are presented in Table D-1. For the FERC relicensing process, PacifiCorp developed the Klamath River Water Quality Model (KRWQM) (Watercourse Engineering, Inc. 2003, PacifiCorp 2004), consisting of linked Resource Management Associates (RMA) RMA-2 and RMA-11 dimensional models for riverine segments, where RMA-2 simulates riverine hydrodynamics and RMA-11 simulates water quality processes, and a 2-dimensional CE-QUAL-W2 model used for water quality in reservoir segments. The KRWQM does not include an analysis for the Klamath River Estuary. The KRWQM possesses the following attributes (Tetra Tech 2009a):

- Uses proven and generally accepted hydrodynamic and water quality models, including historical application to the Klamath River;
- Has been reviewed by a number of stakeholders in the watershed;
- Can be directly compared to many Oregon Department of Environmental Quality (DEQ), North Coast Regional Water Quality Control Board (North Coast Regional Board) and tribal water quality criteria;
- Has been calibrated for the Klamath River; and,
- Uses the public domain model CE-QUAL-W2 and a version of RMA that can be distributed to the public.

KRWQM results for water temperature and dissolved oxygen compare the existing condition (all Project dams in place) to four without-dams scenarios (i.e., without Iron Gate Dam ["WIG"]; without Copco No. 1, Copco No. 2, and Iron Gate dams ["WIGC"]; without J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams ["WIGCJCB"]; and without Keno, J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams ["WOP" and "WOP2"]). Model runs were calibrated using data from calendar years 2001–2004 (PacifiCorp 2004). General modeling assumptions in comparison to conditions considered for this EIR water quality effects analyses are presented in Table D-2. Limitations and sources of uncertainty for the KRWQM are presented in Watercourse Engineering, Inc. (2003).

D.1.2 Klamath River TMDL Model

For development of Klamath River Total Maximum Daily Loads (TMDLs) in Oregon and California, Oregon DEQ, North Coast Regional Board, and the United States Environmental Protection Agency (USEPA) Regions 9 and 10 collaborated to enhance the existing KRWQM by revisiting assumptions for several model algorithms, including the three-dimensional Environmental Fluid Dynamics Code model, to represent water quality in the Klamath River Estuary. Algorithm enhancements are described in Tetra Tech (2009a). The Klamath River TMDL model was calibrated for water temperature, dissolved oxygen, nutrients (TP, TN, ortho-phosphorus, nitrate, ammonia), and pH using year 2000 data, with the exception of the Klamath River Estuary which was calibrated

[6] Here numeric models refers to mathematical models that are developed to represent the physical, chemical, and biological conditions in waterbodies such as rivers, lakes, reservoirs, wetlands, estuaries, and the ocean.

using year 2004 data. Additional model corroboration was conducted for Klamath River reaches in Oregon using data from year 2002, indicating that the Klamath River TMDL model scenarios reproduce general temporal and spatial trends in the observed data (Tetra Tech 2009a). Four simulated scenarios were run for the Klamath River TMDL model including the following (Tetra Tech 2009b):

- Natural conditions baseline scenario (T1BSR)—applies to the Upper, Middle, and Lower Klamath River;
- Oregon TMDLs allocation scenario (TOD2RN)—applies to the Hydroelectric Reach to the Oregon-California state line (RM 214.1);
- California TMDLs allocation scenario (TCD2RN)—applies to the Hydroelectric Reach downstream from the Oregon-California state line (RM 214.1) and the Middle and Lower Klamath River; and,
- With-dams Oregon and California TMDLs scenario (T4BSRN)—applies to the Upper, Middle, and Lower Klamath River.

General modeling assumptions in comparison to conditions considered for this EIR's water quality effects analyses are presented in Table D-2. As shown in Table D-2, the historically natural Keno Reef was included in place of Keno Dam, such that the Keno Reach is not characterized as a free-flowing river for the T1BSR, TOD2RN, and TCD2RN Klamath River TMDL model runs. All dams were retained in the analysis for T4BSRN including Link River, Keno, J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate dams. In the analysis for this EIR, only the dams within the area of analysis were considered. Other modeling assumptions, limitations, and sources of uncertainty for the Klamath River TMDL model are presented in Tetra Tech (2009a).

Table D-1. Numeric Models Used to Assess Potential Water Quality Impacts for the Proposed Project and Alternatives.

Reach	Water Quality Parameter					
	Water Temperature	**Sediment and Turbidity**	**Dissolved Oxygen**		**Nutrients**	**pH**
	Long-term[1]	**Short-term[2]**	**Short-term[2]**	**Long-term[1]**	**Long-term[1]**	**Long-term[1]**
No Project Alternative, Continued Operations with Fish Passage Alternative						
Downstream from J.C. Boyle Reservoir (RM 229.8)	Klamath TMDL T4BSRN Klamath TMDL T1BSR RBM10			Klamath TMDL T4BSRN Klamath TMDL T1BSR	Klamath TMDL T4BSRN	Klamath TMDL T4BSRN
Oregon-California State line (RM 214.1)						
Downstream from Iron Gate Dam (RM 193.1)						
Shasta River (RM 179.5)						
Scott River (RM 145.1)						
Seiad Valley (RM 132.7)						
Salmon River (RM 66.3)						
Trinity River (RM 43.3)						
Turwar (RM 5.6)						
Klamath River Estuary (RM 0-3.9)						
Proposed Project, Partial Removal Alternative, No Hatchery Alternative						
Downstream from J.C. Boyle Reservoir (RM 229.8)	Klamath TMDL TOD2RN			Klamath TMDL TOD2RN	Klamath TMDL TOD2RN	Klamath TMDL TOD2RN
Oregon-California State line (RM 214.1)						
Downstream from Iron Gate Dam (RM 193.1)	Klamath TMDL TCD2RN KRWQM WIGCJCB[3] RBM10	Reclamation SRH-1	Reclamation, USFWS, USGS, Stillwater Sciences BOD/IOD	Klamath TMDL TCD2RN KRWQM WIGCJCB[3]	Klamath TMDL TCD2RN	Klamath TMDL TCD2RN
Shasta River (RM 179.5)						
Scott River (RM 145.1)						
Seiad Valley (RM 132.7)						
Salmon River (RM 66.3)						
Trinity River (RM 43.3)						
Turwar (RM 5.6)						
Klamath River Estuary (RM 0-3.9)						

<table>
<tr><th rowspan="3">Reach</th><th colspan="6">Water Quality Parameter</th></tr>
<tr><th>Water Temperature</th><th>Sediment and Turbidity</th><th colspan="2">Dissolved Oxygen</th><th>Nutrients</th><th>pH</th></tr>
<tr><th>Long-term[1]</th><th>Short-term[2]</th><th>Short-term[2]</th><th>Long-term[1]</th><th>Long-term[1]</th><th>Long-term[1]</th></tr>
<tr><td colspan="7">Three Dam Removal Alternative, Two Dam Removal Alternative</td></tr>
<tr><td>Downstream from J.C. Boyle Reservoir (RM 229.8)</td><td rowspan="2"></td><td rowspan="10" colspan="2"></td><td rowspan="2"></td><td rowspan="10" colspan="2"></td></tr>
<tr><td>Oregon-California State line (RM 214.1)</td></tr>
<tr><td>Downstream from Iron Gate Dam (RM 193.1)</td><td rowspan="5">KRWQM WIGC[3]

RBM10</td><td rowspan="5">KRWQM WIGC[3]</td></tr>
<tr><td>Shasta River (RM 179.5)</td></tr>
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<tr><td>Turwar (RM 5.6)</td></tr>
<tr><td>Klamath River Estuary (RM 0-3.9)</td></tr>
</table>

[1] Long-term—greater than 2 years following dam removal/construction of fish passage facilities or greater than 5 years for the No Project Alternative

[2] Short-term—less than 2 years following dam removal/construction of fish passage facilities or 1–5 years for the No Project Alternative.

[3] KRWQM results available for the mainstem immediately downstream from Iron Gate Dam, Scott River confluence, and Salmon River confluence (PacifiCorp 2004).

Key:

Klamath TMDL T4BSRN—with-dams Oregon and California TMDLs allocation scenario (Tetra Tech 2009b).

Klamath TMDL T1BSR—natural conditions baseline scenario for California TMDLs (Tetra Tech 2009b). The T1BSR natural conditions scenario is useful for analyzing those water quality parameters that rely on a comparison to background or natural levels for regulatory water quality standards, such as water temperature and dissolved oxygen.

Klamath TMDL TOD2RN—Oregon TMDLs allocation scenario (Tetra Tech 2009b).

Klamath TMDL TCD2RN—California TMDLs allocation scenario (Tetra Tech 2009b).

KRWQM WIGCJCB—Klamath River Water Quality Model Without Iron Gate, Copco No. 1, Copco No. 2, and J.C. Boyle dams scenario (Watercourse Engineering, Inc. 2003, PacifiCorp 2004).

KRWQM WIGC – Klamath River Water Quality Model Without Iron Gate, Copco No. 1, and Copco No. 2 dams scenario (Watercourse Engineering, Inc. 2003, PacifiCorp 2004).

RBM10—water temperature model including climate change and BO and KBRA flows (Perry et al. 2011).

Reclamation SRH-1—1-dimensional sedimentation and river hydraulics model (Huang and Greimann 2010, USBR 2012).

BOD/IOD—biological oxygen demand (BOD)/immediate oxygen demand (IOD) spreadsheet model developed in collaboration with Reclamation, USGS, and USFWS (Stillwater Sciences 2011).

Table D-2. Comparison of Assumptions and Parameters for Available Numeric Models to Conditions Used for the Assessment of Potential Water Quality Impacts.

Assumptions/Model Parameters	Available Numeric Models for Long-term Conditions			Conditions Considered for Lower Klamath Project EIR			
	KRWQM	Klamath TMDL	RBM10	Proposed Project, Partial Removal Alternative, No Hatchery Alternative	No Project and Continued Operations with Fish Passage Alternative	Three Dam Removal	Two Dam Removal
Water quality constituents considered	• Water temperature [1] • Dissolved oxygen[1] • Nutrients • Chlorophyll-a	• Water temperature • Dissolved oxygen • Nutrients • pH • Chlorophyll-a	• Water temperature	• Water temperature • Suspended material • Dissolved oxygen • Nutrients • pH • Chlorophyll-a			
Dams remaining in-place (different modeling scenario names are shown in quotations for KRWQM and the Klamath TMDL model)	• “WOP” and “WOP2” = Link River • “WIGCJCB” = Link River and Keno • “WIGC” = Link River, Keno, J.C. Boyle • “WIG” = Link River, Keno, J.C. Boyle, Copco No. 1 and 2 • “EC” = Link River, Keno, J.C. Boyle, Copco No. 1 and 2, Iron Gate	• “T4BSRN” = Link River, Keno, J.C. Boyle, Copco No. 1 and 2, Iron Gate • “TOD2RN” and “TCD2RN” = Link River and Keno Reef [2] • “T1BSR” = Link River and Keno Reef [2]	“No Action Alternative” = J.C. Boyle, Copco No. 1, Copco No. 2, Iron Gate	None	J.C. Boyle, Copco No. 1, Copco No. 2, and Iron Gate	J.C. Boyle	J.C. Boyle and Copco No. 2

Assumptions/Model Parameters		Available Numeric Models for Long-term Conditions: KRWQM	Available Numeric Models for Long-term Conditions: Klamath TMDL	Available Numeric Models for Long-term Conditions: RBM10	Conditions Considered for Lower Klamath Project EIR: Proposed Project, Partial Removal Alternative, No Hatchery Alternative	Conditions Considered for Lower Klamath Project EIR: No Project and Continued Operations with Fish Passage Alternative	Conditions Considered for Lower Klamath Project EIR: Three Dam Removal	Conditions Considered for Lower Klamath Project EIR: Two Dam Removal
Flows		• Existing conditions for 2000–2004 [3] • NMFS 2002 Biological Opinion Mandatory Flows for the Klamath Project	Existing conditions for 2000 [4]	2010 Biological Opinion Mandatory (NMFS) and KBRA Flows[5]	See Section 3.1.6	See Sections 4.2.1.2 and 4.4.1.1	See Section 4.6.1.1	See Section 4.5.1.1
Reaches		Link River Dam (RM 259.7) to Turwar (RM 5.6)	Link River Dam (RM 259.7) to the Klamath River Estuary (RM 0–3.9)	Link River Dam (RM 259.7) to the Pacific Ocean	J.C. Boyle Reservoir (RM 233.3) to the Klamath River Estuary (RM 0–3.9)			
Analysis year(s)		2000–2004	2000	2012–2061	As detailed in EIR Sections 3 and 4			
Climate change		Not included	Not included	Included				
Nutrients	Upper Klamath Lake and inputs to Keno Impoundment[6]	Current conditions at the time of the model development[7]	OR and CA full TMDL compliance [8]	Not applicable	• Eventual OR and CA full TMDL compliance[8] • Timescale assumed to be decades			
	Small tributaries to the lower Klamath River (i.e., Iron Gate Dam to Klamath River Estuary)	• TN: 0.275 mg/L • TP: 0.075 mg/L	• TN: 0.077 mg/L [10] • TP: 0.014 mg/L [10]	Not applicable	See assumptions for Klamath TMDL			

Assumptions/Model Parameters		Available Numeric Models for Long-term Conditions: KRWQM	Klamath TMDL	RBM10	Conditions Considered for Lower Klamath Project EIR: Proposed Project, Partial Removal Alternative, No Hatchery Alternative	No Project and Continued Operations with Fish Passage Alternative	Three Dam Removal	Two Dam Removal
Algae and particulate organic matter (POM)	Upper Klamath Lake and inputs to Keno Impoundment[6]	Current conditions at the time of the model development[7]	OR and CA full TMDL compliance[8]	Not applicable	• OR and CA full TMDL compliance[8] • Timescale unknown			
	Settling rates in all reservoirs	• Algal settling rate = 1.0 m/day • POM = 0.5 m/day [9]	• Algal settling rate = 0.3 m/day [11] • POM = 0.8 m/day [11]	Not applicable	See assumptions for Klamath TMDL			

[1] Published results available for water temperature and dissolved oxygen in PacifiCorp (2005). Additional results available in the FERC record and as an electronic appendix to http://www.riverbendsci.com/reports-and-publications-1/klam_wq_model_eval.pdf

[2] The historically natural Keno Reef was included in place of Keno Dam, such that the Keno Reach is not characterized as a free-flowing river.

[3] The WOP2 scenario has "smoothed flows" from Klamath Irrigation Project, to account for the fact that if Keno Dam were removed, Link releases would have to be smoothed due to instream flow requirements downstream.

[4] Exceptions to current conditions include the TIBSR model (natural conditions) where dramatically increased summer flows (i.e., no diversions) were assumed for tributaries to the mainstem Klamath River. USBR 2005 "un-depleted natural flows" were used for flows at Link River Dam and Keno Impoundment. For T4BSRN, TOD2RN, and TCD2RN, Shasta River flows are increased by 45 cfs. Hydropower peaking in the J.C. Boyle Peaking Reach was not included in the no-dam scenarios (TOD2RN, TCD2RN, T1BSR) (Tetra Tech 2009a).

[5] While analysis for the Lower Klamath Project EIR considered the 2013 Joint Biological Opinion and the court-ordered flushing and emergency dilution flows, the KBRA and 2013 Joint Biological Opinion flows were determined to be sufficiently similar (see Section 3.1.6) that modeling using KBRA flows was used if modeling using 2013 Joint Biological Opinion flows was not available.

[6] Upper Klamath Lake and inputs to Keno impoundment are model boundary inputs for the available numeric models only. The area of analysis for water quality constituents in the Lower Klamath Project License Surrender only considers the Klamath River in Oregon from J.C. Boyle Reservoir to the Oregon-California State line to the extent that conditions in that reach influence water quality in California. See Section 3.2.1 for further details.

[7] Current conditions at the time of the model development based on combination of individual samples and long-term monthly averages (used when individual samples not available) from Freemont Bridge (near outlet of Upper Klamath Lake, Link Dam, and Eastside/Westside powerhouses. Current conditions at the time of the model development for other inputs to Keno Impoundment are based on combination of individual samples and averages.

[8] Full implementation assumes the decrease in nutrient loads at the Oregon-California State line is 87% for TP and 62% for TN and BOD (calculated from information in Table 2-8, Kirk et al. [2010]). Analysis for the Lower Klamath Project EIR only considered OR TMDL compliance with regard to what crosses the Oregon-California State line into California and how it may influence water quality in the Upper, Mid-, and Lower Klamath Basin in California.

[9] PacifiCorp (2005).

[10] North Coast Regional Board (2010).

[11] Tetra Tech (2009a).

D.1.3 RBM10 Model

The one-dimensional RBM10 water temperature model was developed as part of the Secretarial Determination studies in 2010 and 2011. The RBM10 model is well suited to the temporal, spatial, and structural requirements for simulating water temperatures in the Klamath Basin because it can (1) predict mean daily water temperature along a longitudinal gradient of a river, (2) accommodate both reservoir and river sections, and (3) simulate long time series (50 years) quickly (Perry et al. 2011). RBM10 was used to simulate water temperatures for 2012–2061 under two management alternatives ("BO" [Biological Opinion], which represents the No Project Alternative, and "KBRA", which represents the Proposed Project). RBM10 includes six future climate scenarios (i.e., 12 fifty-year simulations). The six future climate scenarios represent hydrology and meteorology using the Index Sequential Method and five alternative Global Circulation Models (GCMs; USBR 2012). The Index Sequential Method generates flows based on historical hydrology and meteorology under future operational conditions (USBR 2012)

D.1.4 Considerations for the Lower Klamath Project

As presented in Table D-2, major differences between the existing numeric models and the conditions considered for water quality analyses in this EIR include the following:

- The Klamath River TMDL TOD2RN and TCD2RN ("dams out") model runs remove PacifiCorp dams and represent Keno Dam as the historical natural Keno Reef, such that the Keno Reach is not characterized as a free-flowing river. The KRWQM includes a model run retaining Keno. The analysis in this EIR retains Keno Dam for the Proposed Project and all alternatives.
- River flows for the Lower Klamath Project EIR analysis are based on the NMFS and USFWS 2013 Joint Biological Opinion flows (NMFS and USFWS 2013) and the court-ordered flushing and emergency dilutions flows (U.S. District Court 2017), but modeling using KBRA flows are used if modeling using the 2013 Joint Biological Opinion flows are not available. The KBRA and 2013 Joint Biological Opinion flows are sufficiently similar (see Section 3.1.6) that modeling using KBRA flows still captures the range of conditions under 2013 Joint Biological Opinion flows. The river flows used in the Lower Klamath Project EIR analysis tend to be greater than those modeled in either the Klamath River TMDL model (with the exception of T1BSR) or the KRWQM.
- Climate change was not considered in either the KRWQM or the Klamath River TMDL model.
- The RBM10 water temperature model includes climate change projections, but uses NMFS 2010 Biological Opinion (NMFS 2010) flows "BO" alternative for the "No Action Alternative" analyzed in the Secretarial Determination studies and KBRA flows for the "Action Alternative" analyzed in the Secretarial Determination studies.

To place the Proposed Project analysis in the proper context, the above differences are generally considered as part of the water quality effects determinations whenever numeric model results are utilized.

Additionally, two models have been developed for the Secretarial Determination process to determine potential short-term impacts under the Proposed Project on suspended sediment and dissolved oxygen downstream from the Lower Klamath Project dams. The first, a one-dimensional sedimentation and river hydraulics model (SRH-1D), was developed to simulate existing conditions for hydraulics and sediment transport downstream from Iron Gate Dam as well as predict suspended sediment concentrations under multiple drawdown scenarios of the Proposed Project. The SRH-1D model uses three “water year types” defined by the probability that in a given year the river could experience flows exceeding the low-level outlet capacities of the reservoirs (i.e., ability of the low-level outlet to evacuate the major portion of the reservoir storage volume by gravity flow) between March and June; a typical “dry year” is defined as having a 10 percent probability of exceedance (i.e., Water Year[7] [WY] 2001), a median year has a 50 percent probability of exceedance (i.e., WY 1976), and a typical wet year has a 90 percent probability of exceedance (i.e., WY 1984) (USBR 2012). The SRH-1D modeling uses KBRA and NMFS 2010 Biological Opinion (NMFS 2010) flows, but the flow requirements in the Klamath River have changed since the modeling was performed. NMFS and USFWS 2013 Joint Biological Opinion flows are the main flow requirements in the Klamath River. KBRA and NMFS 2010 Biological Opinion flows and 2013 Joint Biological Opinion flows are sufficiently similar (see Section 3.1.6) that modeling results using KBRA flows represent the range of conditions under 2013 Joint Biological Opinion flows (USBR 2016). Modeling assumptions, limitations and sources of uncertainty are presented in Huang and Greimann (2010) and USBR (2012).

The second model developed for the Secretarial Determination process is a simplified spreadsheet model used to investigate the potential influences that re-suspension of reservoir sediments may have on short-term dissolved oxygen levels downstream from Iron Gate Dam. Developed in collaboration with USBR, USGS, and USFWS, the model uses results from a combination of *in situ* sampling of reservoir sediments and water quality, and laboratory analysis of oxygen demand from the resuspended reservoir sediments, combined with numerical modeling of biochemical oxygen demand, immediate oxygen demand, sediment oxygen demand and oxygen demand as a function of suspended sediment concentrations and other variables. The short-term dissolved oxygen modeling uses outputs from USBR modeling that utilizes KBRA flows, but as previously discussed the modeling results using KBRA flows capture the range of conditions under 2013 Joint Biological Opinion flows (USBR 2016). Modeling assumptions, limitations and sources of uncertainty are presented in Stillwater Sciences (2011).

D.2 Environmental Effects Determination Methodology for Short-term Suspended Sediments

The North Coast Regional Board developed the Desired Conditions Report (2006) as a guidance document describing sediment-related indices of importance to salmonid habitat conditions, including the application of the Newcombe and Jensen (1996) Severity Index and the Suspended Sediment Dose Index. The Suspended Sediment Dose Index relates exposure time to suspended sediment using a natural logarithm relationship, while the Severity Index provides a ranking of the effects of suspended sediment on salmonids, as shown below for coho salmon.

Suspended Sediment Dose Index (SSDI) = ln x (suspended sediment [mg/L] x exposure time [hrs])

[7] Water year is defined as October 1 to September 30.

Severity Index (coho salmon) = 0.7523 x SSDI + 0.5735

The North Coast Regional Board guidance document suggests that a Severity Index Rank of 4.0 or greater represents significant harm to salmonids so as to be detrimental to the beneficial use associated with cold freshwater habitat (North Coast Regional Board 2006). This ranking would equate to a suspended sediment concentration of 0.15 mg/L and a Suspended Sediment Dose Index of 3.9 (Table D-3 below), assuming 2 weeks exposure for salmonids as a chronic condition that is likely to occur under a dam removal scenario. However, the general significance criteria adopted for this analysis state that an impact must result in *substantial* adverse effects on beneficial uses of water to be considered significant. For the Lower Klamath Project EIR water quality analysis, a continuous suspended sediment concentration of 100 mg/L for a 2-week chronic exposure condition is considered to be a substantial impact, because this exposure corresponds to a Severity Index Rank of 8.4 (Table D-3), which generally spans the transition from sublethal effects (8 = long-term reduction in feeding rate and feeding success, poor condition) to lethal effects (9 = delayed hatching, reduced fish density) for exposed salmonids (Newcombe and Jensen 1996).

Table D-3. Calculated Suspended Sediment Dose Index (SSDI) and Severity Index Rank for a Range of Suspended Sediment Concentrations (SSCs). Based on Newcombe and Jensen (1996).

SSC (mg/L)	SSDI[1]	Severity Index Rank
0.15	3.9	3.5
0.5	5.1	4.4
1	5.8	4.9
4	7.2	6.0
10	8.1	6.7
30	9.2	7.5
60	9.9	8.0
100	10.4	8.4
200	11.1	8.9
800	12.5	10.0
3,000	13.8	11.0
7,000	14.7	11.6

[1] Based on 2-week exposure period as a chronic condition.

A more detailed analysis of suspended sediment effects on key fish species, including consideration of specific life history stages, suspended sediment concentrations, and exposure period, is required for a comprehensive assessment of the impacts of the Proposed Project alternatives on the cold water designated beneficial use. This level of analysis is presented in Section 3.3 Aquatic Resources and appendices to that section, including additional background regarding the applicability of the Newcombe and Jensen (1996) Severity Index Ranks and the Suspended Sediment Dose Index for key fish species in the Klamath River. Further discussion of particular effects of suspended sediment on shellfish and estuarine and marine organisms is also presented in Section 3.3.5.1 Aquatic Resources.

D.3 Environmental Effects Determination Methodology for Inorganic and Organic Contaminants

The Secretarial Determination sediment evaluation process followed screening protocols of the Sediment Evaluation Framework (SEF) for the Pacific Northwest, issued by the interagency Regional Sediment Evaluation Team (RSET) 2009 and updated in 2016. The SEF is a regional guidance document that provides a framework for the assessment and characterization of freshwater and marine sediments in Idaho, Oregon, and Washington (RSET 2009, 2016). Level 2A of the SEF involves a data screening assessment to compare reservoir sediment data to available and appropriate sediment maximum levels (MLs), screening levels (SLs), and bioaccumulation triggers (BTs); and, Level 2B, including bioassays, bioaccumulation tests and special evaluations such as elutriate chemistry and risk assessments (CDM 2011).

The set of sediment MLs, SLs, and BTs included in the Secretarial Determination process for Level 2A of the SEF represented an array of screening tools for different potential effects scenarios and are (briefly) the following:

- **Pacific Northwest SEF** sediment screening levels for standard chemicals of concern and chemicals of special occurrence in marine and freshwater bulk sediments for Idaho, Oregon, and Washington (RSET 2009, 2016)[8];
- **Dredged Material Management Program (DMMP)** screening levels (SL), bioaccumulation thresholds (BT), and maximum levels (MT) for marine sediments[9] in Puget Sound, Washington;
- **Screening Quick Reference Tables (SQuiRTs)** guideline values compiled by NMFS, covering organic and inorganic contaminants in a variety of environmental media, including marine and freshwater sediments;
- **Oregon DEQ bioaccumulation screening level values (BSLVs)** for humans and relevant classes of wildlife (e.g., freshwater fish, birds, mammals);
- **California Human Health Screening Levels** are concentrations of hazardous chemicals in soil or soil gas that the California Environmental Protection Agency considers to be below thresholds of concern for risks to human health**;** and,
- **USEPA Regional Screening Levels** (formerly Preliminary Remediation Goals) for assessing human health long-term (i.e., 24-yr) exposure risk for contaminated soils and sediments in various settings (USEPA 1991, 1996, 2002).

Additional information regarding the screening levels is presented in CDM (2011), along with the compilation of SL values. For the Secretarial Determination process, the sediment screening values have been used in a step-wise manner to systematically consider potential impact pathways under each of the Project alternatives (or later, during subsequent permitting actions). The applicability of each of the screening levels

[8] Similar numeric chemical guidelines for the assessment and characterization of freshwater and marine sediments do not exist for California. The State Water Board is in the process of developing and adopting sediment quality objectives (SQOs) for enclosed bays and estuaries. However, the California SQOs are designed to assess in-place, surficial sediments as opposed to deeper sediment deposits or sediment discharges. As such, the California SQOs are not considered particularly relevant to the Secretarial Determination process or the Lower Klamath Project EIR effects assessment.

[9] The DMMP guidelines do not include numeric values for freshwater sediments.

to the Lower Klamath Project EIR effects determination analysis varies depending on the Project alternative (Table D-2).

Level 2B testing under the SEF consists of biological testing (bioassays or tissue analyses) or other special evaluations that are completed to provide more empirical evidence regarding the potential for sediment contamination to have adverse effects on receptors (RSET 2009). While tests involving undiluted sediments identify potential contamination that could affect bottom-dwelling (benthic) organisms, tests using suspension/elutriates of dredged material assess potential water column toxicity. For freshwater ecosystems that contain salmonid species, rainbow trout (*Oncorhynchus mykiss*) is recommended as one of the elutriate test species. A bioaccumulation evaluation is undertaken under SEF Level 2B when bioaccumulative chemicals of concern compared to screening levels either exceed or are inconclusive, and thus need further evaluation to determine if they pose a potential risk to human health or ecological health in the aquatic environment (RSET 2009, 2016).

Results from elutriate chemistry, sediment bioassays, and elutriate bioassays carried out for the Secretarial Determination studies were used to provide additional information beyond simple comparisons of sediment contaminant levels to regional or national screening levels (CDM 2011). Elutriate data was evaluated through comparison with a suite of regional, state, and federal standards for water quality (Tables D-4 and D-5); the comparison was first carried out without consideration of dilution as a conservative approach. The results of sediment and elutriate bioassays were analyzed for acute toxicity potential for two benthic organisms (*Chironomus dilutus, Hyalella azteca*) and one freshwater fish (*Onchorhynchus mykiss*). *Chironomus dilutus* and *Hyalella azteca* are national "benchmark" toxicity indicator species, as identified in the joint USEPA–United States Army Corps of Engineering (USACE) Inland Testing Manual for the evaluation of dredged material proposed for discharge into waters of the United States, as follows:

> *Benchmark species comprise a substantial data base, represent the sensitive range of a variety of ecosystems, and provide comparable data on the relative sensitivity of local test species. Other species may be designated in future as benchmark species by USEPA and the US Army Corps of Engineers when data on their response to contaminants are adequate. Only benthic species should be tested. Although sediment dwellers are preferable, intimate contact with sediment is acceptable. Note that testing with all recommended taxa is not required; however, at least one [benchmark] amphipod taxon should be tested* (USEPA and USACE 1998).

Table D-4. Applicable Screening Levels for Determination of Potential Toxicity and Bioaccumulation Effects from Sediment-Associated Contaminants Under the Proposed Project and Alternatives.

Screening Level	No Project	Full Removal (Proposed Project)	Partial Removal	Continued Operations of the Lower Klamath Project With Fish Passage	Three Dam Removal
Pacific Northwest Sediment Evaluation Framework (SEF)					
Marine (SL1, SL2*)		X	X		X
Freshwater (SL2, SL2*)	X	X	X	X	X
Puget Sound Dredged Materials Management Program (DMMP)					
Marine (SL, BT, ML)		X	X		X
SQuiRT Values					
Marine (ERL, ERM, T20, TEL, T50, PEL)		X	X		X
Freshwater (TEL, LEL, PEL, SEL, TEC, PEC)	X	X	X	X	X
Oregon DEQ Bioaccumulation Screening Level Values (BSLVs)					
Freshwater (Fish, Bird-Individual, Bird-Population, Mammal-Individual, Human-General, Human-Subsistence)	X	X	X	X	X
USEPA Regional Screening Levels (RSLs)					
Residential Soil Supporting (Total Carcinogenic, Total Non-carcinogenic)	X	X	X	X	X

Screening Level	No Project	Full Removal (Proposed Project)	Partial Removal	Continued Operations of the Lower Klamath Project With Fish Passage	Three Dam Removal
California Human Health Screening Levels (CHHSLs)					
Residential Soil Supporting (Total Carcinogenic, Total Non-carcinogenic)	X	X	X	X	X

* SL2's have been removed from the Pacific Northwest SEF; however, they are shown here because they were part of the SEF at the time that the intensive sediment investigation on the Lower Klamath Project reservoirs was ongoing.

Screening Level Key:

- SL1= Sediment Screening Level 1—SEF lower (more protective) sediment screening level value.
- SL2= Sediment Screening Level 2—SEF higher (less protective) sediment screening level value.
- SL= Screening Level - a guideline value defined for each DMMP chemical of concern that identifies concentrations at or below which there is no reason to believe that dredged material disposal would result in unacceptable adverse effects.
- BT= Bioaccumulation Trigger represents the sediment concentration that constitutes a "reason to believe" level that the chemical would accumulate in the tissues of target organisms for bioaccumulative chemicals of concern. Sediments with chemical concentrations above the calculated BT require bioaccumulation testing before suitability for open-water disposal can be determined.
- ML= Maximum Level represents a guideline value derived for each chemical of concern which represents the highest Apparent Effects Threshold (AET)—a chemical concentration at which biological indicators show significant effects.
- SQuiRTs= Screening Quick Reference Tables developed by NMFS to screen natural resources of concern.
- ERL= Effects Range Low represents the chemical concentration below which adverse effects would be rarely observed.
- ERM= Effects Range Median represents the chemical concentration above which adverse effects would frequently occur.
- T20= Chemical concentration representing a 20% probability of observing an effect, calculated using individual chemical logistic regression models based on 10-day survival results from marine amphipod tests (Ampelisca a. and Rhepoxynius a.).
- TEL= Threshold Effect Level represents the concentration below which adverse effects are expected to occur only rarely.
- T50= Chemical concentration representing a 50% probability of observing an effect, calculated using individual chemical logistic regression models based on 10-day survival results from marine amphipod tests (Ampelisca a. and Rhepoxynius a.).
- PEL= Probable Effect Level represents the concentration above which adverse effects are expected to occur frequently.
- LEL= Lowest Effect Level represents the concentration at which sediments are considered to be clean to marginally polluted. No effects on the majority of sediment-dwelling organisms are expected below this concentration.
- SEL= Severe Effect Level represents the concentration at which sediments are considered to be heavily polluted. Adverse effects on the majority of sediment-dwelling organisms are expected when this concentration is exceeded.
- TEC= Threshold Effect Concentration represents the concentration at which adverse effects are not expected to occur.
- PEC= Probable Effect Concentration represents the concentration at which above which adverse effects are expected to occur more often than not.

Table D-5. Applicable Water Quality Criteria for Determination of Potential Toxicity and Bioaccumulation Effects from Sediment-Associated Contaminants Under the Proposed Project and Alternatives.

Water Quality Criteria	No Project	Full Removal (Proposed Project)	Partial Removal	Continued Operations of the Lower Klamath Project With Fish Passage	Three Dam Removal
North Coast Regional Board Basin Plan					
Freshwater (Aquatic Life CTR, Aquatic Life NTR)	X	X	X	X	X
Human Health (Primary MCL, Secondary MCL, Agriculture, Human Health CTR, Human Health NTR)	X	X	X	X	X
California Ocean Plan					
Marine (Aquatic Life Chronic, Aquatic Life Acute, Aquatic Life Instant)		X	X		X
Human Health (CAR, NCAR, Water and Organism)		X	X	X	X
CCR-California Department of Public Health					
Human Health (DLR, MCL)	X	X	X	X	X
National Regional Water Quality Criteria Priority Pollutants					
Freshwater (CMC, CCC)	X	X	X	X	X
Marine (CMC, CCC)		X	X		X
Human Health (Water and Organism, Organism Only)	X	X	X	X	X
National Regional Water Quality Criteria Non-priority Pollutants					
Freshwater (CMC, CCC)	X	X	X	X	X
Marine (CMC, CCC)		X	X		X
Human Health (Water and Organism, Organism Only)	X	X	X	X	X

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